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14. ABSTRACT  <b>Objective:</b> The goal of this study was to investigate head impacts, neuropsychological performance and cerebral blood flow in intercollegiate boxers to increase understanding about consequences of head impacts in this population. If significant correlations were found between measures, recommendations for increasing efficiency of head impact assessment in combat environments might be made. <b>Method:</b> Participants-31 intercollegiate male boxers mean age 20.74 yrs., height 70.14 in., weight 164.32 lbs., & experience 1.5 yrs. Assessments occurred before and after two full-effort 2 minute sparring rounds. The Impact Headgear system tracked location/number of head impacts, translational acceleration, & rotational forces. The ImPACT test and Automated Neuropsychological Assessment Metrics (ANAM) measured neuropsychological performance and the Brain Acoustic Monitor (BAM) measured cerebral blood flow. Sparring bouts were videotaped to validate head impacts. <b>Results:</b> Impact Headgear recorded an average of 26.81 impacts per boxer, most of which were below the 25% probability for brain injury. The ImPACT test showed a decrease in verbal memory (p<.05), delayed memory (p<.01) and improved reaction time (p<.01). The ANAM showed a decrease in delayed memory (p<.01) and improved reaction time (p<.01). BAM detected no significant changes and no significant correlations were found between the BAM and the neuropsychological measures. <b>Conclusion:</b> In the current sample, head impacts were below threshold to cause brain disturbance detectable through BAM; however, consistent with research in amateur boxing, mild decline in memory function was detected. Research with a larger sample across greater impacts is recommended to further investigate the efficacy of the BAM.		

<b>15. SUBJECT TERMS</b> Mild Traumatic Brain Injury (MTBI), Concussion, Head Impact, Head Injury, Head Acceleration, MBTI Diagnostics, Cognitive Testing, Brain Acoustic Monitoring, Boxing, Neuropsychology					
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**FINAL REPORT**

**AN INVESTIGATION OF HEAD ACCELEROMETRY, COGNITIVE FUNCTION, AND  
BRAIN BLOOD FLOW DURING INTERCOLLEGIATE BOXING AND ITS IMPACT  
REGARDING HEAD INJURY ASSESSMENT IN COMBAT**

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**UNCLASSIFIED**

# An Investigation of Head Accelerometry, Cognitive Function, and Brain Blood Flow during Intercollegiate Boxing and its Impact Regarding Head Injury Assessment in Combat



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## OBJECTIVE

The goal of the study was to investigate head impacts, neuropsychological performance and cerebral blood flow in intercollegiate boxers to increase understanding about consequences of head impacts in this population.

Also, if significant correlations were found between measures, recommendations for increasing efficiency of head impact assessment in combat environments could be considered.

## INTRODUCTION

Relatively little is known about the biomechanics of these mild injuries and their cognitive and neurophysiological sequelae.

In addition to its known occurrence in sports, mild traumatic brain injury (mTBI) is a signature wound of the current military conflicts in Iraq and Afghanistan with 15-28% of military personnel sustaining such injuries (Hoge et al., 2008; Okie, 2005). With increased demand for accurate measures in-theater, it has become clear that conventional assessment in this setting can be challenging, thereby compromising test results. With this comes potential attendant risk of secondary injury.

Collegiate boxing provides an opportunity to study the effect of mTBI on central nervous system structure and function (Stojisih, et al., 2008) and to evaluate the validity of neurophysiological measures in the rapid assessment of head injuries.

## METHOD

28 male boxers were assessed before & after two-2 min., 100% effort, sparring rounds with an opponent in the same weight class & ability.

**Age:** 20.21 (SD=1.77) yrs.

**Ht:** 70.14 (SD=2.97) in.

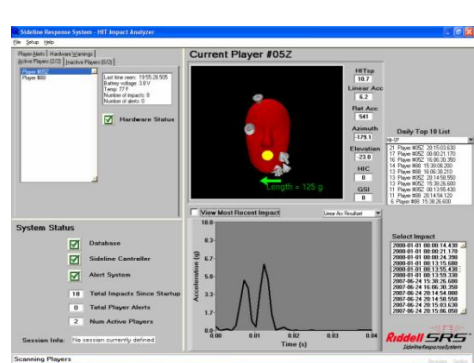
**Wt.:** 164.32 (SD=23.04) lbs.

**Boxing experience:** 1.50 (SD=1.40); range 0-5) yrs.

### Head Impact Monitoring:

Instrumented Boxing Headgear (IBH; Simbex, Inc.) is a wireless system which records number/location of impacts & strength/type of head acceleration. All bouts were videotaped to validate head impact data.

IBH Screen Shot



### Brain Acoustic Monitoring (BAM):

BAM is an indirect measure of cerebral blood flow which uses a sensor attached to the forehead to detect sound waves generated by arterial blood flow. It has been validated in a brain injured population.

Figure: BAM Apparatus



### Neuropsychological Assessments:

**ANAM4™ TBI:** Automated Neuropsychological Assessment Metrics-v.4-TBI Battery

**ImPACT ©:** Immediate Post-concussion Assessment and Cognitive Testing v.5; computerized

### Neuropsychological Results: ImPACT

\* p<.05; \*\*\*p<.001

	Pre-bout	Post-bout	Paired t-test
	Mean (SD)	Mean (SD)	
<b>Impact Composite Score</b>			
Verbal Memory	.902 (.072)	.859 (.111)	2.498*
Visual Memory	.843 (.105)	.795 (.107)	1.911
Processing Speed	43.471 (6.984)	44.749 (6.284)	-1.416
Reaction Time	.540 (.061)	.505 (.051)	4.207***
Impulse Control	7.570 (5.392)	7.210 (5.593)	0.556
Memory Acquisition (correct)	.926 (.051)	.913 (.066)	1.094
Delayed Memory	.895 (.100)	.830 (.100)	4.014***

### Neuropsychological Results: ANAM4

\*p<.05; \*\*p<.01; p\*\*\*<.001; (SD)

	Mean RT			# Correct			Throughput		
	Pre	Post	t-test	Pre	Post	t-test	Pre	Post	t-test
<b>Simple RT</b>	233.22 (21.85)	226.52 (26.22)	1.67	37.97 (2.56)	36.29 (3.88)	3.74***	259.37 (23.19)	268.06 (28.55)	-2.00
<b>Code Sub</b>	944.50 (174.50)	947.32 (226.12)	-0.11	70.03 (2.03)	69.19 (2.30)	2.51*	63.54 (10.33)	63.97 (12.84)	-.26
<b>(learning) Procedural RT</b>	519.29 (63.08)	519.42 (75.29)	-0.01	30.48 (1.50)	30.84 (1.00)	-1.12	111.89 (14.60)	114.24 (15.09)	-0.91
<b>Math Processing</b>	2333.96 (607.78)	1968.04 (466.29)	3.82***	18.35 (1.70)	17.90 (1.94)	1.65	25.17 (7.33)	28.87 (6.66)	-3.57***
<b>Match to Sample</b>	1296.92 (379.33)	1339.23 (496.16)	-0.82	19.21 (.96)	18.64 (1.37)	1.22	48.71 (17.42)	46.97 (18.86)	.68
<b>Code Sub (delay)</b>	998.43 (246.35)	965.31 (196.64)	0.73	34.19 (1.74)	31.00 (4.83)	3.93***	59.26 (12.96)	55.13 (15.01)	1.62
<b>Simple RT (2)</b>	253.55 (47.38)	239.39 (49.81)	1.29	38.00 (1.95)	36.45 (3.36)	3.28**	242.44 (32.80)	258.05 (37.69)	-2.03

## RESULTS

### Head Impact Monitoring

Type of Acceleration

	Minimum	Maximum	Mean	Std. Deviation
<b>Peak Lin Acc (g)</b>	5.60	122.50	23.01	14.50
<b>Peak Rot Acc (rad/s<sup>2</sup>)</b>	344.30	10124.60	1721.35	1024.49
<b>HIC-15*</b>	0.30	486.00	21.46	44.90

\*HIC-15 = Head Injury Criterion -a measure of the likelihood of head injury arising from a head impact based on impact measurements taken over 15 msec. Pellman et al., 2003 suggested a HIC threshold of 250 for mild TBI. Lin Acc=linear acceleration; Rot Acc=rotational acceleration

Impact Location

Impact Location	# of Impacts	% of Total Impacts	Trans Accel (g) Mean (SD)	Rot Accel (rad/s <sup>2</sup> ) Mean (SD)	HIC-15 Mean (SD)
Front	298	34.73	22.30 (0.65)	1632.82 (50.20)	18.25 (1.78)
Back	210	24.48	24.40 (1.12)	1898.21 (88.30)	25.71 (3.85)
Left	97	11.31	23.67 (1.75)	1756.22 (101.07)	24.07 (5.58)
Right	235	27.39	23.09 (1.04)	1713.20 (64.42)	22.28 (3.06)
Top	18	2.10	17.37 (1.63)	1457.02 (128.45)	8.81 (1.77)

Note: Trans Accel = Translational Acceleration; Rot Accel = Rotational Acceleration

**BAM:** paired t-tests, \* sig at <.05; ratio<2 /divergence>10 dB TBI indicators

	Pre-bout Mean (SD)	Post-bout Mean (SD)
<b>Left Brain Ratio</b>	3.95 (0.18)	2.91 (0.16)*
<b>Right Brain Ratio</b>	3.93 (0.19)	2.88 (0.12)*
<b>Left Brain Peak Divergence (dB)</b>	4.52 (0.59)	5.21 (0.78)
<b>Right Brain Peak Divergence (dB)</b>	5.12 (0.60)	5.01 (0.66)

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## SUMMARY

- 99.2% of impacts < Head Injury Criterion of 250 for probable mild TBI
- Pre to post changes in neuropsychological measures:
  - ImPACT:** decreased verbal & delayed memory; decreased reaction time
  - ANAM4:** increased vigor; decreased learning & recall of number-symbol pairs; decreased math reaction time
- BAM ratio scores significantly changed pre to post, but no scores were indicative of TBI. Changes were most likely due to post-bout increases in heart rate.
- No statistically significant changes were found in BAM divergence measures.
- No significant correlations were found between BAM and neuropsychological measures.

## DISCUSSION

Consistent with research in amateur boxing (Stojisih, et al., 2008), mild decline in memory function was detected following head impacts in collegiate boxers; however, no significant change in cerebral blood flow indicative of mTBI was detectable through BAM.

Future work should examine the association between discrete classes of head impacts and cognitive changes post-bout and include a larger sample across greater impacts to better evaluate the utility of BAM in identifying concussion in-theater. Follow-up assessments are also recommended to examine the persistence of the deficit.